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(71) Applicant: MIDTRONICS, INC. [US/US]; 8230 South Madison Street, Burr Ridge, IL 60521 (US).

(72) Inventor: BERTNESS, Kevin, I.; 1317 McClurg Drive, Batavia, IL 60510 (US).

(74) Agents: CHAMPLIN, Judson, K. et al.; Westman, Champlin & Kelly, P.A., International Centre - Suite 1600, 900 Second Avenue South, Minneapolis, MN 55402-3319 (US).

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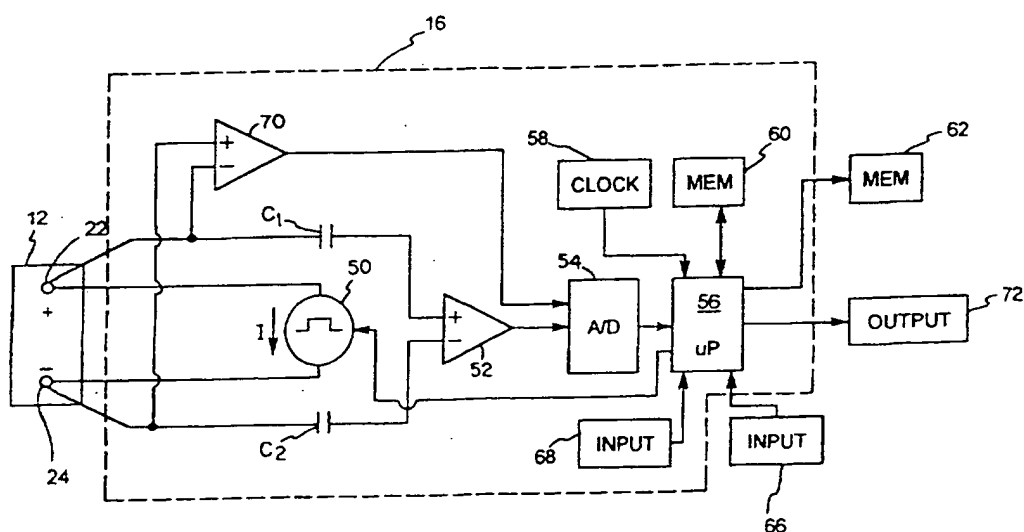
(57) Abstract

A method and apparatus for auditing condition of a storage battery (12) performs a battery test on the storage battery (12) to obtain a test result. Test condition information is obtained related to conditions of the battery test. The battery test result and the test condition information are combined into a code. The code may be subsequently used to determine conditions during the battery test which lead to the particular test result.

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METHOD AND APPARATUS FOR AUDITING A BATTERY TEST

BACKGROUND OF THE INVENTION

The present invention relates to testing
storage batteries. More specifically, the present
invention relates to generating a code related to a
battery test.

Storage batteries, such as lead acid storage
batteries of the type used in the automotive industry,
have existed for many years. However, understanding the
nature of such storage batteries, how such storage
batteries operate and how to accurately test such
batteries has been an ongoing endeavor and has proved
quite difficult. Storage batteries consist of a
plurality of individual storage cells electrically
connected in series. Typically each cell has a voltage
potential of about 2.1 volts. By connecting the cells
in series, the voltages of the individual cells are
added in a cumulative manner. For example, in a typical
automotive storage battery, six storage cells are used
to provide a total voltage when the battery is fully
charged of 12.6 volts.

There has been a long history of attempts to
accurately test the condition of storage batteries. A
simple test is to measure the voltage of the battery.
If the voltage is below a certain threshold, the battery
is determined to be bad. However, this test is
inconvenient because it requires the battery to be
charged prior to performing the test. If the battery is
discharged, the voltage will be low and a good battery
may be incorrectly tested as bad. Furthermore, such a
test does not give any indication of how much energy is
stored in the battery. Another technique for testing a

battery is referred as a load test. In a load test, the battery is discharged using a known load. As the battery is discharged, the voltage across the battery is monitored and used to determine the condition of the
5   battery. This technique requires that the battery be sufficiently charged in order that it can supply current to the load.

More recently, a technique has been pioneered by Dr. Keith S. Champlin for testing storage batteries
10 by measuring the conductance of the batteries. This technique is described in a number of United States patents obtained by Dr. Champlin, for example, U.S. Patent No. 3,873,911, issued March 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE;
15 U.S. Patent No. 3,909,708, issued September 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,816,768, issued March 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,825,170, issued April 25, 1989, to
20 Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Patent No. 4,881,038, issued November 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC
25 CONDUCTANCE; U.S. Patent No. 4,912,416, issued March 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; and U.S. Patent No. 5,140,269, issued August 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING
30 BATTERY/CELL CAPACITY.

As battery test results have become more accurate, and the repeatability of those results has increased, we have recognized a new problem. Specifically, if a subsequent battery test is performed

at a later time and perhaps at a different location and under different conditions, there is no adequate way to compare the results of the two tests. It is impossible to determine if differences in test results are due to improper use of the test equipment, inaccurately recorded test results or even falsification of the test results. For example, this problem can be particularly vexing to battery manufactures, battery distributors, and automobile companies who offer warranties with their batteries. Further, the precise conditions of the test and test results would be useful in determining the cause of the failure and reducing the likelihood of failure in new batteries by identifying and correcting defects.

SUMMARY OF THE INVENTION

The present invention offers solutions to problems associated with the aforementioned problems. The present invention provides a method and apparatus for auditing a battery test. In the method, a battery test is performed on a storage battery to obtain a test result. Test condition information is obtained regarding conditions related to the battery test. The test result and the test condition information is combined into a code and the code is stored or output for future reference.

Similarly, the apparatus includes battery test circuitry for performing a battery test on the storage battery and providing a test result. Input circuitry receives test condition information which is related to conditions of the battery test. Calculation circuitry coupled to the battery test circuitry and the input circuitry combines the battery test result and the test condition information and responsively provides a code output.

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In various embodiments of the invention, the code output can be used to subsequently analyze the battery test in view of the test conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

5   Figure 1 is a simplified schematic diagram showing battery monitoring and auditing circuitry in accordance with the present invention.

Figure 2 is a simplified block diagram shown the steps of a method in accordance with the invention.

10   ### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a new and useful technique for monitoring and auditing a battery test of a storage battery, such as a lead acid storage battery. The present invention is for use with any

15   battery tester or testing technique and those discussed herein are strictly as examples. The present invention provides a method and apparatus for combining the result of a battery test with information related to conditions of the battery test into a code which can be

20   subsequently accessed. As described herein, the present invention is useful in subsequent analysis of batteries which failed the battery test and may be used to monitor batteries returned on warranty, to monitor operator performance and can be used in detecting and identifying

25   a faulty design of a storage battery.

Figure 1 is a simplified block diagram of battery monitoring circuitry 16 in accordance with the present invention. Apparatus 16 is shown coupled to battery 12 which includes a positive battery terminal 22

30   and a negative battery terminal 24.

Circuitry 16 operates in accordance with one embodiment of the present invention and determines the conductance (G_{BAT}) of battery 12 and the voltage potential (V_{BAT}) between terminals 22 and 24 of battery

12.   Circuitry 16 includes current source 50, differential amplifier 52, analog-to-digital converter 54 and microprocessor 56. Amplifier 52 is capacitively coupled to battery 12 through capacitors C_1 and C_2.

5   Amplifier 52 has an output connected to an input of analog-to-digital converter 54. Microprocessor 56 is connected to system clock 58, memory 60, memory 62 and analog-to-digital converter 54. Microprocessor 56 is also capable of receiving an input from input devices 66

10   and 68. Microprocessor 56 also connects to output device 72.

In operation, current source 50 is controlled by microprocessor 56 and provides a current I in the direction shown by the arrow in Figure 1. In one

15   embodiment, this is a square wave or a pulse. Differential amplifier 52 is connected to terminals 22 and 24 of battery 12 through capacitors C_1 and C_2, respectively, and provides an output related to the voltage potential difference between terminals 22 and

20   24. In a preferred embodiment, amplifier 52 has a high input impedance. Circuitry 16 includes differential amplifier 70 having inverting and noninverting inputs connected to terminals 24 and 22, respectively. Amplifier 70 is connected to measure the open circuit

25   potential voltage (V_{BAT}) of battery 12 between terminals 22 and 24. The output of amplifier 70 is provided to analog-to-digital converter 54 such that the voltage across terminals 22 and 24 can be measured by microprocessor 56.

30   Circuitry 16 is connected to battery 12 through a four-point connection technique known as a Kelvin connection. This Kelvin connection allows current I to be injected into battery 12 through a first pair of terminals while the voltage V across the

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terminals 22 and 24 is measured by a second pair of connections. Because very little current flows through amplifier 52, the voltage drop across the inputs to amplifier 52 is substantially identical to the voltage
5   drop across terminals 22 and 24 of battery 12. The output of differential amplifier 52 is converted to a digital format and is provided to microprocessor 56. Microprocessor 56 operates at a frequency determined by system clock 58 and in accordance with programming
10   instructions stored in memory 6ᴖ.

       Microprocessor 56 determines the conductance of battery 12 by applying a current pulse I using current source 50. The microprocessor determines the change in battery voltage due to the current pulse I
15   using amplifier 52 and analog-to-digital converter 54. The value of current I generated by current source 50 is known and is stored in memory 60. In one embodiment, current I is obtained by applying a load to battery 12. Microprocessor 56 calculates the conductance of battery
20   12 using the following equation:

$$Conductance = G_{BAT} = \frac{\Delta I}{\Delta V} \qquad\qquad Equation\ 1$$

where ΔI is the change in current flowing through battery 12 due to current source 50 and ΔV is the change in battery voltage due to applied current ΔI.

25   Based upon the battery conductance G_{BAT} and the battery voltage, the battery tester 16 determines the condition of battery 12. For example, if the battery conductance G_{BAT} is lower than a predetermined threshold for a particular battery at a particular voltage,
30   microprocessor 56 determines that battery 12 has failed the battery test. For example, as explained in the Champlin patents, the tester can compare the measured

CCA (Cold Cranking Amp) with the rated CCA for that particular battery. Microprocessor 56 uses information input from input device 66 provided by, for example, an operator, etc. This information may consist of the
5 particular type of battery, location, time, the name of the operator. Additional information relating to the conditions of the battery test is received by microprocessor 56 from input device 68. Input device 68 may comprise one or more sensors, for example, or other
10 elements which provide information such as ambient or battery temperature, time, date, humidity, barometric pressure, noise amplitude or characteristics of noise in the battery or in the test result, or any other information or data which may be sensed or otherwise
15 recovered which relates to the conditions of the test, how the battery test was performed, or intermediate results obtained in conducting the test. Additional test condition information is provided by microprocessor 56. Such additional test condition information may
20 include the values of G_{BAT} and battery voltage, the various inputs provided to battery tester 16 by the operator which may include, for example, type of battery, estimated ambient or battery temperature, type of vehicle (i.e., such as provided through the Vehicle
25 Identification Number (VIN) code for the vehicle) or the particular sequence of steps taken by the operator in conducting the test. In accordance with the present invention, microprocessor 56 uses some, or all, of the various battery test condition information and combines
30 such test condition information with the test result to generate a code. This code is provided to output device 72 which may comprise, for example, a display or a printer. In another embodiment, the code is stored in memory 62 for subsequent use. As used herein, input

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circuitry refers to any circuitry used to obtain the test condition information and may include inputs 66 and 68, memory 60, etc.

The code of the present invention may be generated through any appropriate technique. Two examples follow.

For example, the display 72 will indicate: "TEST CODE: A0XXXX1YYYY2222Z".

Where the information is encoded as follows:

A: Alphanumeric code representing geographic territory

0:              0 = no temperature compensation used in conditioning the test.
                1 = temperature compensation used in conditioning the test.

XXXX: Entered battery rating in coded CCA (Cold Cranking Amps) (0=A, 1=B, 2=C, etc.) I.E. "0625 CCA" displayed as AGCF

1:              Result of battery test:
                0 = Good -- Return to Service
                1 = Good -- Recharge & Return to Service
                2 = Recharge & Retest
                3 = Bad battery
                4 = Bad cell battery

YYYY: Measured coded battery voltage without decimal point (0=A, 1=B, etc.) I.E. "12.65 Volts" displayed as BCGF

2222:   Actual CCA measured by tester.

Z: Alphanumeric code representing state of charge.

An example using eight characters follows. A pseudo base 26 number, represented by two alpha characters, is used to represent certain values in this test code.

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For example, to convert the coded number "CZ", look up the alpha characters in the following table:

A=0	B=1	C=2	D=3	E=4	F=5
G=6	H=7	I=8	J=9	K=10	L=11
M=12	N=13	O=14	P=15	Q=16	R=17
S=18	T=19	U=20	V=21	W=22	X=23
Y=24	Z=25				

Table 1

Take the first letter, "C", and multiply its value by 26. Then add the value of the second letter "Z": {"C" x 26} + "Z".

$$(2) \; X \; (26) = 52. \hspace{3cm} \text{Equation 2}$$

$$52 + 25 = 77. \hspace{3cm} \text{Equation 3}$$

The coded number is 77.

The display 72 will indicate "TEST CODE: XX0YY1ZZ", for example.

The information is encoded as follows:

XX: Entered coded battery rating in 5 CCA increments. For example, 360 CCA would be represented as 72, 650 CCA as 130, etc. CCA will be rounded to the nearest 5 CCA value. The coded CCA is then represented using the Pseudo Base 26 scheme listed above. 360 CCA = 72 coded = CU. 650 CCA = 130 = FA.

0: Result code:
0 = Good -- Return to Service
1 = Good -- Recharge & Return to Service
2 = Recharge & Retest
3 = Bad battery
4 = Bad cell battery

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5 = Good -- Return to Service (temperature compensated during test)

6 = Good -- Recharge & Return to Service (temperature compensated during test)

7 = Recharge & Retest (temperature compensated during test)

8 = Bad battery (temperature compensated)

9 = Bad cell battery (temperature compensated)

YY: Measured coded voltage in 50mVolt increments. For example, 10.00 volts would be represented as 200, 12.75 volts as 255, etc. Voltage will be rounded to the nearest 50mVolt value. The coded voltage is then represented using the Pseudo Base 26 scheme listed above. 10.00 volts = 200 coded = HS. 12.75 volts = 255 = JV.

1: Numeric code representing state of charge. The state of charge of the battery is indicated by a single numeric character. "0" represents that SOC is not applicable, such as in Replace Battery or Recharge and Retest. "5" represents 100% state of charge. "1"- "4" are divided in equal steps between a selected lower percentage and 100% relative conductance.

ZZ: Actual measured battery cranking power in 5 CCA increments. For example, 360 CCA would be represented as 72, 650 CCA as 130, etc. CCA will be rounded to the nearest 5 CCA value. The coded CCA is then represented using the Pseudo Base

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26 scheme listed above.   360 CCA = 72

coded = CU.   650 CCA = 130 = FA.

Figure 2 is a simplified block diagram showing

steps in accordance with the method of the present

5   invention.   Figure 2 shows flow chart 100 which

initiates operation at start block (or step) 102.   At

block 104, user input is obtained.   For example, user

input is obtained through input device 66 and may

constitute instructions for performing a battery test,

10   the rated cold cranking amps (CCA) for the batter under

test, estimated temperature during the test for

temperature compensation during the test or any other

user input related to the test or test environment.

This information is provided to microprocessor 56 and is

15   stored in memory 60 for use during the test. Additional

information may relate to a particular vehicle in which

the battery in installed which may be obtained, for

example, using the VIN code for the vehicle. Further,

the make, model and manufacturer of the battery 12 may

20   be provided.   Other such information includes battery

specific information, such as a serial number, digital

signature for tracking and identifying the battery,

make, model, and date of manufacture of the battery,

etc. Such information may be manually input or, for

25   example, read from a bar code carried on the battery.

At block 106, microprocessor 56 performs the

battery test using the techniques described above.

However, it will be understood that those techniques are

merely examples and the battery test may be any battery

30   test including a simple voltage measurement test, a load

test, resistance, conductance, impedance, admittance, or

other parameter test, battery capacity or state of

charge test, digital hygrometer test in which the

specific gravity of the battery acid is measured,

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complex charging and discharging tests which are known
in the art, etc. It will be understood that in various
embodiments of the present invention, the particular
test may be selected from any available or yet to be
5   discovered battery test.

At block 108, microprocessor 56 obtains any
additional condition information which may be used in
accordance with the invention. As explained above, the
information may be any information related to the test
10   such as actual ambient or battery temperature sensed by
device 68, various intermediate test results which were
obtained in performing the test at step 106, various
battery parameters such as surface charge, voltage,
conductance, resistance, float current, noise amplitude,
15   noise frequency or other noise characteristics, etc. At
step 110, microprocessor 56 combines the condition
information obtained at step 108 with the test results
obtained at step 106 into a string of information. The
information may be of any form and is not limited to the
20   character code described above. The information may be
digitally encoded into a series of data bytes. However,
in one preferred embodiment, an alpha numeric code is
preferred. This combination of information is referred
to herein as a code. At block 112, this code is output
25   using an appropriate technique. For example, the code
can be output on output device 72 which may be a
display, printer, label printer, bar code printer, modem
or other data transmission means, etc. In another
variation on the invention, the step 112 provides the
30   output to memory 62 for subsequent use. For example, a
plurality of codes may be collected in memory for
subsequent output or analysis. At block 114, the
procedure ends.

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One advantage of the present invention is that it is particularly useful in ensuring compliance with the warranty return policies of manufacturers. For example, if, upon identifying a faulty battery, the operator marks the battery 12 with the code provided on output device 72, for example, by marking directly on the battery or applying a sticker to the battery when the battery is returned, the manufacturer will have information regarding the test which resulted in the return of the battery. In one preferred embodiment, the code is encrypted or otherwise difficult to duplicate whereby the code cannot be falsified. Thus, the manufacturer may then perform a subsequent test on the battery and compare the subsequent test result with the result obtained which lead to the warranty return. This will make it very difficult for the unscrupulous individual to return a battery under a warranty policy where the battery is not faulty. Furthermore, the invention provides additional traceability of the batteries which are being returned to the manufacturer in that the particular code may contain geographic and location information used to identify the particular test location and operator which lead to the failed test. Further still, if the battery is in a new car and is being returned to the automobile manufacturer, the manufacturer can retrieve information regarding the vehicle such as through the VIN code of the vehicle.

The present invention provides a convenient technique for a manufacturer to collect information regarding batteries which fail battery tests. Such information can be used in improving future batteries or identifying faults in existing batteries. For example, the code can contain information regarding the various intermediate steps or measurements which are obtained in

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providing the battery test. This could be, for example, battery recovery voltage, voltage after a first test, voltage after a second test, surface charge voltage, voltage or current in response to an implied load or

5 signal, temperature compensation input, noise amplitude or other noise characteristics, float current, etc.

The present invention may be used with standby batteries such as those used to power remote telephone switching locations, computer facilities, power company

10 facilities, pumping stations, etc. It will be understood by those skilled in the art that the present invention is not limited to automotive storage batteries.

In one embodiment of the invention, the code

15 is in an encrypted format to thereby reduce the likelihood of code falsification. In the two examples described above, the code is encrypted in that it is difficult for a user who is unfamiliar with the particular coding technique to discover the precise

20 technique being used and generate valid codes which contain falsified information. A further embodiment of the invention includes providing a stronger encryption algorithm which may be as simple as an offset or transposition cipher or a more complex technique such as

25 a public key encryption technique. Such a technique can also be used to apply a digital signature to the code containing, for example, information about the particular battery tester being used.

Although the present invention has been

30 described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. For example, one may use other input mechanisms to obtain test condition

information or employ other battery tests than those explicitly described. Further, the code may be generated using any appropriate technique.

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WHAT IS CLAIMED IS:

1.   An apparatus for monitoring the condition of
a storage battery, comprising:

        battery test circuitry for performing a
           battery test on the storage battery,
           providing an intermediary test result
           output, and providing a battery test
           result based upon the intermediary test
           result output; and

        calculation circuitry coupled to the battery
           test circuitry combining the battery
           test result and the intermediary test
           result output and responsively providing
           a code output.

2.   The apparatus of claim 1 wherein the
intermediary test result information includes battery
voltage.

3.   The apparatus of claim 1 including input
circuitry receiving test condition information related
to conditions of the battery test, wherein the
calculation circuitry provides the test code output
further in response to the test condition information.

4.   The apparatus of claim 3 wherein test
condition information includes information related to
temperature.

5.   The apparatus of claim 3 wherein test
condition information includes geographic information.

6.   The apparatus of claim 3 wherein test
condition information includes information related to
the vehicle containing the battery.

7.   The apparatus of claim 3 wherein test
condition information includes information related to
the battery.

8.   The apparatus of claim 1 wherein the intermediary test result output comprises battery conductance.

9.   The apparatus of claim 1 wherein the intermediary test result output comprises battery response to a resistive load.

10.   The apparatus of claim 1 wherein the intermediary test result output comprises battery resistance.

11.   A method of monitoring the condition of a storage battery, comprising:

connecting a battery test device to the storage battery;

performing a battery test on the storage battery and obtaining an intermediary test result;

obtaining a test result based upon the intermediary test result; and

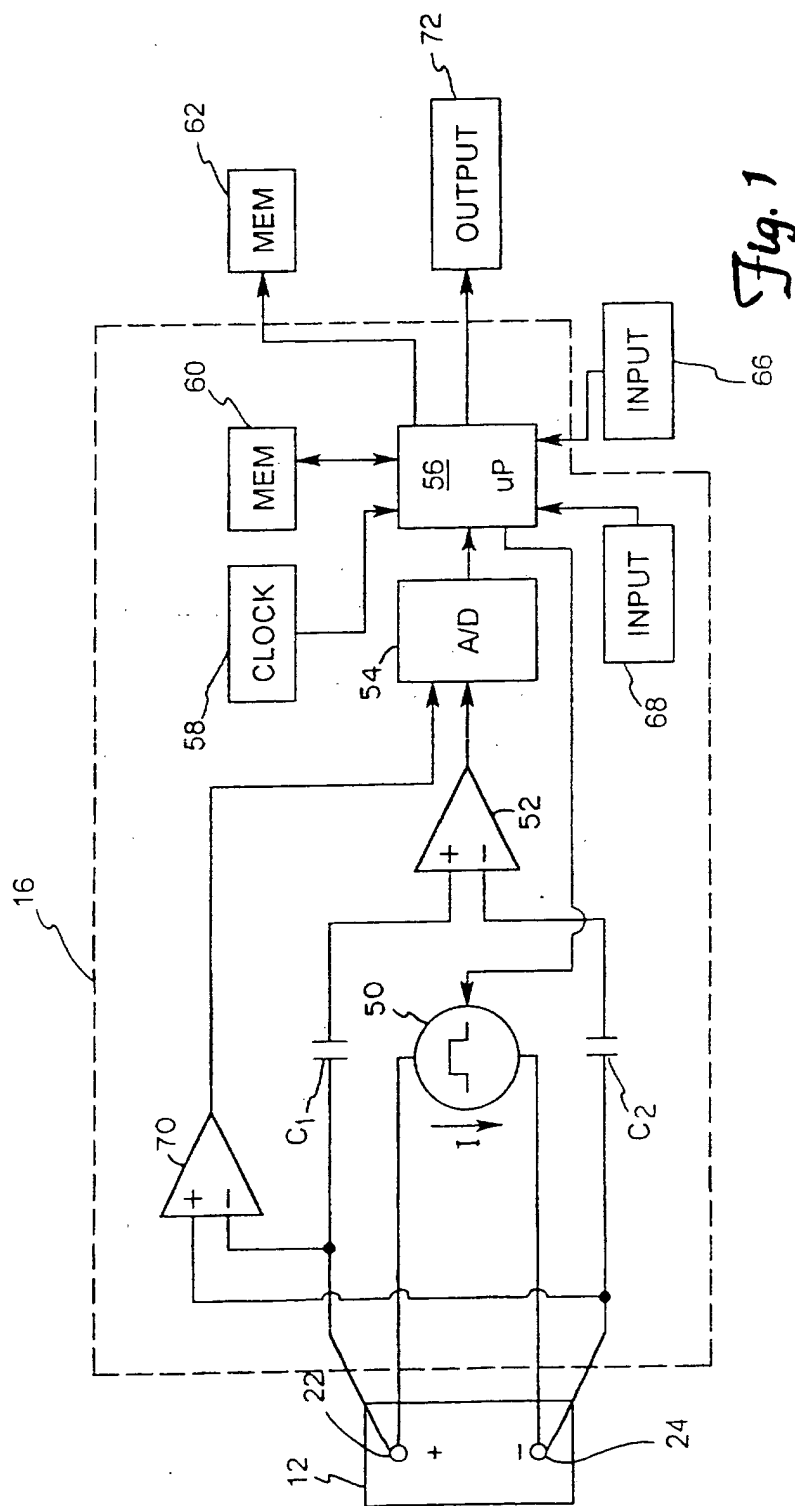combining the test result and the intermediary test result into a code.
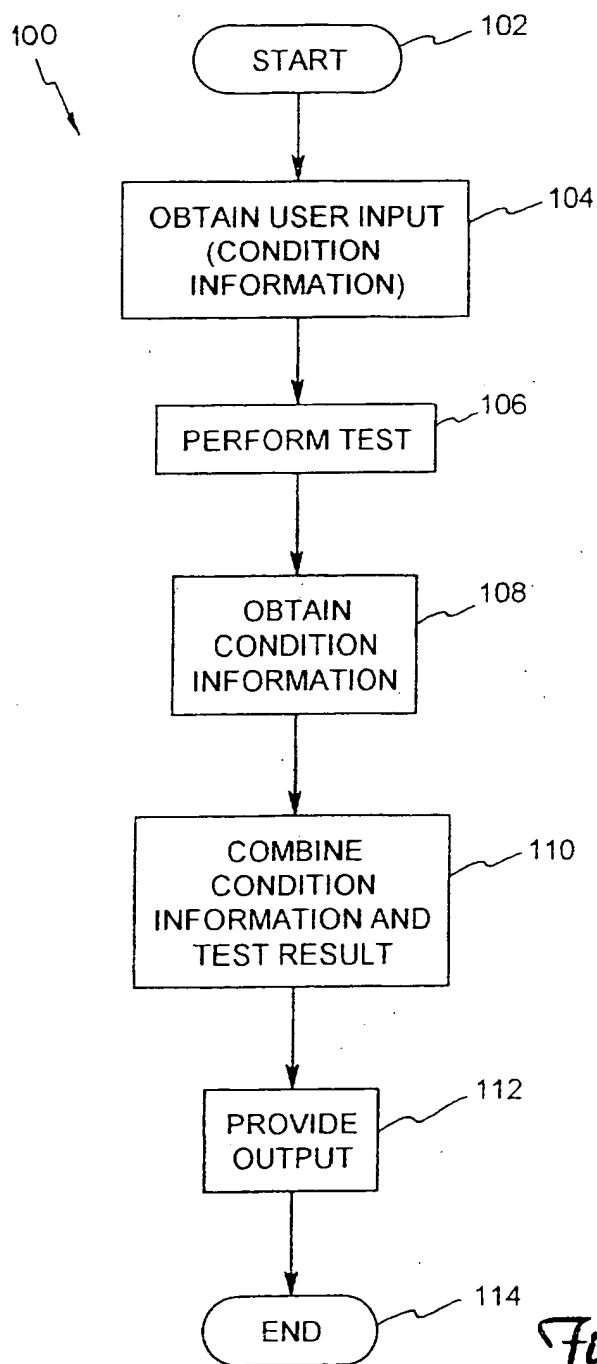
Fig. 1

100

102 — START

104 — OBTAIN USER INPUT (CONDITION INFORMATION)

106 — PERFORM TEST

108 — OBTAIN CONDITION INFORMATION

110 — COMBINE CONDITION INFORMATION AND TEST RESULT

112 — PROVIDE OUTPUT

114 — END

Fig. 2

INTERNATIONAL SEARCH REPORT

A.   CLASSIFICATION OF SUBJECT MATTER

IPC(6)   :G01N 27/42, 04
US CL   :324/426, 433; 340/636
According to International Patent Classification (IPC) or to both national classification and IPC

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. :   324/426, 427, 429, 433; 340/636; 320/48

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
search terms: battery, voltage, test?, display, condition and code

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,514,694 A (FINGER) 30 April 1985, column 16	1 and 18
Y, P	US 5,606,242 A (HULL et al.) 25 February 1997, see the abstract	2-3,4-12,14 -15, 18-24
A	US 5,144,248 A (ALEXANDRES et al.) 01 September 1992, see figure 6	1-10
A	US 5,032,825 A (KUZNICKI) 16 July 1991, see figure 1	1-10
A	US 4,820,966 A (FRIDMAN) 11 April 1989, see the figures	1-10

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed

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"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 OCTOBER 1997 ·	**1 6 DEC 1997**

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Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	MAURA REGAN
Facsimile No. (703) 308-7382	Telephone No. (703) 305-4917

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